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CHANCES Layered Cloud (CLVL) Product — Initial 1-Month Sample

Final Report

John M. Forsythe
Charles A. Chaapel
Mark A. Ringerud
Science and Technology Corporation–METSAT
Fort Collins, Colorado

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Technical Representative: Dr. David Randel

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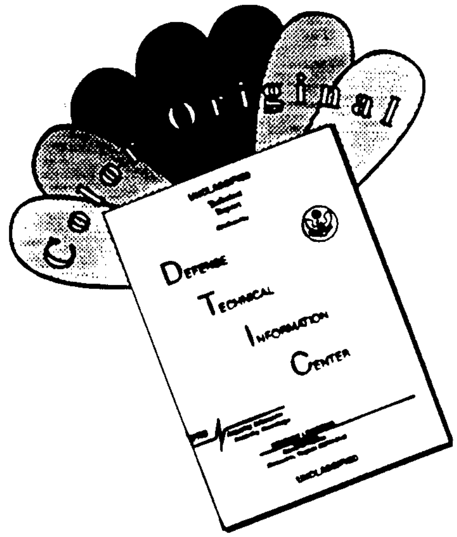

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13. ABSTRACT *(Maximum 200 words)*
The Climatological and Historical ANalysis of Clouds for Environmental Simulations (CHANCES) database was used, with additional supportive data, to produce a multi-layer cloud database for an initial 30-day period in July, 1994 (selected from within the CHANCES database period of February 1994 through January 1995 inclusive). The supportive data include the USAFHigh-Resolution Analysis System (HIRAS) and Surface Temperature data, USAFECCC surface observations (DATSAV2 database), DMSP Special Sensor Microwave Imager (SSM/I) retrievals, and the U.S. Navy topographic database (ETOPO5).

The global satellite image data set that served as the primary input to this layered cloud product is the CHANCES image database. The CHANCES database was built for the USAF Phillips Laboratory by Science and Technology Corporation-METSAT Division (STC-METSAT) under an SBIR Phase II Contract No. F19628-93-C-0197.

In the present study, the 5-km resolution CHANCES infrared image database was the primary satellite radiance input for the location of clouds. The HIRAS analysis and satellite microwave retrievals (e.g. ,SSM/I) were used to provide the vertical moisture distribution for the cloud layer assignments. The surface observations were used as input for both cloud base measurements and estimates. Surface observations were the primary input source over land, and the HIRAS analysis and SSM/I retrievals were the primary data source over the oceans.

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FOREWORD

Science and Technology Corporation (STC)-METSAT is pleased to submit this final technical report entitled, "CHANCES Layered Cloud Product (CLVL)" by John M. Forsythe, Charles R. Chaapel, and Mark A. Ringerud of the STC-METSAT office, Fort Collins, Colorado. This work was performed under the sponsorship of the DoD Center for Geosciences at Colorado State University in collaboration with United States Air Force (USAF) research scientists. The period of performance covered by this final technical report is October 1995 through July 1996.

For the first time ever, at this global resolution, the STC team has delivered an innovative new high space and time resolution ***layered*** cloud database product for a 3-day period in July 1994.

STC-METSAT acknowledges the support and discussions provided during the course of this work by Dr. Arnold Barnes, the USAF Technical Representative. Special thanks are extended to Mr. Donald Reinke and Dr. David Randel, Colorado State University technical experts, for their technical assistance and insights.

LIST OF FIGURES

LIST OF ACRONYMS

AVHRR	Advanced Very High Resolution Radiometer
CHANCES	Climatological and Historical ANalysis of Clouds for Environmental Simulations
CIRA	Cooperative Institute for Research in the Atmosphere
CLVL	CHANCES Levels (CHANCES Layered Cloud)
CNC	Cloud/No Cloud
DATSAV2	USAF Surface Observation Database
DMSP	Defense Meteorological Satellite Program
DoD	Department of Defense
ETOPO5	Navy Topographic database
GMS	Geostationary Meteorological Satellite (Japan)
GOES	Geostationary Operational Environmental Satellite (United States)
HIRAS	High-Resolution Analysis System
HP	Hewlett Packard
IR	Infrared
LZW	Lempel-Ziv-Welch (data compression algorithm)
Meteosat	Meteorological Satellite (European Space Agency)
METSAT	METeorological SATellite - a Division of Science and Technology Corporation
PC	Personal Computer
PCFLOS	Probability-of-Cloud-Free-Line-Of-Sight
PL	Phillips Laboratory (Hanscom AFB, MA)
QA	Quality Assessment
QC	Quality Control
RTNEPH	USAF Real-Time NEPHanalysis
SAO	Surface Airways Observations
SBIR	Small Business Innovation Research
SSM/I	Special Sensor Microwave Imager
STC	Science and Technology Corporation
USAF	United States Air Force
USAFCCC	United States Air Force Combat Climate Center

TECHNICAL ABSTRACT

The Climatological and Historical ANalysis of Clouds for Environmental Simulations (CHANCES) database was used, with additional supportive data, to produce a multi-layer cloud database for an initial 30-day period in July 1994 (selected from within the CHANCES database period of February 1994 through January 1995 inclusive). The supportive data include the USAF High-Resolution Analysis System (HIRAS) and Surface Temperature data, USAFECCC surface observations (DATSAV2 database), DMSP Special Sensor Microwave Imager (SSM/I) retrievals, and the U.S. Navy topographic database (ETOPO5).

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In the present study, the 5-km resolution CHANCES infrared image database was the primary satellite radiance input for the location of clouds. The HIRAS analysis and satellite microwave retrievals (e.g., SSM/I) were used to provide the vertical moisture distribution for the cloud layer assignments. The surface observations were used as input for both cloud base measurements and estimates. Surface observations were the primary input source over land, and the HIRAS analysis and SSM/I retrievals were the primary data source over the oceans.

1. INTRODUCTION

The Climatological and Historical ANalysis of Clouds for Environmental Simulations (CHANCES) database was sponsored by a Small Business Innovative Research (SBIR) Phase II grant to Science and Technology Corporation (STC). The purpose of the Phase II was to produce a 1-hr, 5-km resolution, global cloud/no cloud (CNC) database product and to demonstrate the feasibility of producing a longer term (5-yr) climatological cloud database in Phase III. Figures 1-3 (see Appendix A) show examples of CHANCES input data and the global infrared image and CNC products. The intent of the CHANCES project was to use proven techniques to demonstrate the feasibility of producing a usable high-resolution cloud product from the very significant volume of satellite data available each day. Upon completion of that 1-year data set, a proposal was submitted to the DoD Center for Geosciences at Colorado State University (CSU) to produce a 1-month sample of a layered cloud product produced, primarily, from the CHANCES database. This report provides details of the production of the CHANCES layered cloud product (CLVL) for "CHANCES levels".

2. TECHNICAL OBJECTIVE

The technical objective as stated in the proposed work is:

(a) Use the CHANCES satellite database and supportive ancillary data to produce and deliver a 1-month, global, layered cloud database at 1-hr intervals, and 5-km resolution. The layered cloud database will be archived on the global 5-km CHANCES grid. Each grid point will contain the occurrence of cloud within the defined layers, the highest cloud top, and quality analysis information about the process used to determine the layered information. The layered cloud data will be archived on 8 mm tape with one data day per tape. (Note: Appendix B contains the CLVL Users Guide and Appendix C contains the Database Format specifications.)

Two images will be produced for each 1-hr time period. The first is the *Layer Image* which contains the cloud layer information. The second is the *QA Image* that contains information about the input data and processing procedure.

LAYER IMAGE

One 8-bit data word per 5-km data point for a total of 32 Mb per image. Bits 1-8 contain a binary cloud/no cloud flag for each 1.5 km thick layer. The first layer represents cloud below 1.5 km, the second from 1.5 km to less than 3 km, and so on to the top layer which represents cloud above 10.5 km (see Appendix C).

QA IMAGE

One 8-bit word per 5-km data point for a total of 32 Mb per image. The QA image contains information about the input satellite image and supportive data used to perform the layer analysis (see Appendix C).

3. INPUT DATA

Appendix D shows a data flow diagram with the input data used in this project. The HIRAS database was used to produce cloud layer estimates based on the potential for cloud. Similarly, surface observation reports were decoded to produce an independent layered cloud product. Both the HIRAS and surface data-based images were then used to build the layer image where current satellite image data is not available or to supplement the satellite-derived layered cloud product.

Separately, the CHANCES database (Vonder Haar et al., 1995) was interrogated to determine whether a pixel had been identified as cloudy. If the pixel was cloudy, the supportive temperature profile databases were used to determine the cloud top based on the infrared cloud top temperature at that point. The next step was to use the intermediate supportive databases to determine whether cloud was present in each layer beneath the cloud top. For example, if the CHANCES database indicated a cloud with a top in the "high" layer and the intermediate moisture image indicated sufficient moisture in the "middle" layer, both the middle and high layers were set to "1" to indicate cloud.

Section 5.0, "Data Processing", gives additional details about how each of the input data sets was processed, both independently and as a combined data set.

3.1 Satellite Data

Satellite imagery that served as input to the CLVL processing was the archived CHANCES radiance image database from the Phase II CHANCES project (Figure A-2). The database consists of both geostationary and polar-orbiter data that have been merged onto a global, 5-km, 1-hr database.

The following table describes the detector characteristics for the meteorological satellite platforms that were used in the production of the CHANCES database.

	USAF DMSP	GMS	GOES	METEOSAT	NOAA AVHRR
Visible Wavelength (mm)	0.4-1.1	0.50-0.75	0.55-0.75	0.40-1.1	0.58-0.68
Infrared Wavelength (mm)	10.5-12.6	10.5-12.5	10.5-12.6	10.5-12.5	10.3-11.3
Infrared Wavelength AVHRR Channel 3 (mm)					3.55-3.93
Nominal subpoint resolution of raw imagery processed for CHANCES (km)	2.7	5	VIS - 4 IR - 6.8	5	4
Approximate geostationary satellite resolution at 55° from subpoint (km)		12	10	11	

3.2 Ancillary Data

The three supportive databases used in this project are the USAF surface temperature database, the USAF snow and ice database, and the U.S. Navy ETOPO5 topography database. The topography database is static, whereas the surface temperature and snow and ice databases are analysis products that are built at the USAF Air Force Global Weather Central (AFGWC) and archived at the USAFECCC at Scott AFB, Illinois.

3.2.1 USAF HIRAS Database

The HIRAS database consists of 2.5 degree resolution gridded fields with upper level temperature, relative humidity, and winds for mandatory levels from the surface through the top of the troposphere. The database is updated every 6 hours and, therefore, had to be interpolated to hourly files to be matched with the 1-hour resolution CHANCES database. Due to the strong influence of the global rawinsonde network on the HIRAS database, the actual time resolution is realistically 12 hours. This is not ideal but is, unfortunately, the best time resolution that is available for upper air moisture analyses.

3.2.2 SSM/I Data

These data were provided by STC-METSAT. STC-METSAT is currently processing these data to produce the multi-year NVAP global water vapor product (under NASA Contract No. NASW-4715).

3.2.3 Topography and Geopolitical Mapping Databases

Topographic data are taken from the U.S. Navy ETOPO5 database. This database gives elevation data only and is on a 10-km resolution grid. This is the highest resolution topographic database that was available to STC-METSAT. This database was used to determine the elevation of the CHANCES grid points and also as an initial input to the land and water mask.

The final CHANCES land and water mask and geopolitical boundary map graphics used in the image alignment process were produced from the World Vector Shoreline database. This database (courtesy of the Defense Mapping Agency) was produced at scale equivalents from 1:43,000,000 to 1:50,000. The vector shoreline data were provided by the NGDC in Boulder, Colorado.

3.2.4 USAF Surface Observations Database

This database is a reformatted version of standard global surface weather observations. The raw observations are quality controlled and reformatted into the USAF DATSAV2 database format. Decoders were written to further reformat the DATSAV2 into a more compact file structure for CLVL. Only those observational items that were of interest were saved for use in the CLVL processing. These items include station ID, date/time, temperature, dewpoint, cloud (sky cover) amount, cloud bases, and present weather. In addition, a separate database was built that contains the station elevation, latitude and longitude, and station identification for all of the surface reporting stations that were included in the DATSAV2 data.

4. EQUIPMENT

Due to the significant processing load (over 2.3 Gb per data day) and the image display requirements (for both development and QC), it was necessary to use three high-speed workstations to do the bulk of the processing. The data were processed on a VAX 4000-90, and two HP 9000-735 series workstations.

5. DATA PROCESSING

The infrared temperatures and cloud detection from the CHANCES database were merged with several additional datasets to create the CLVL layered cloud product. Before these datasets could be combined, various reformatting and quality control operations were performed. These steps are described below.

5.1 Quality Control of CHANCES Data

Several known anomalies in the original CHANCES database were corrected in order to eliminate spurious cloud detections. These anomalies originally arose from a variety of sources and are described in more detail in Vonder Haar et al., 1995. While they only affected a small portion (less than 1 percent) of the entire CHANCES dataset, the effect could be significant in certain local regions. While STC-METSAT was under no contractual obligation to correct these anomalies under the CLVL contract, they were corrected where technically possible. These anomalies and a brief description of the correction applied are described below.

5.1.1 False clouds near coastlines cue to visible image misalignment

A mask of coastal areas was created, and the CHANCES images were searched in a 7 x 7 pixel area along the mask for clouds indicated in visible data but not in IR data. Clouds found in the original CHANCES database were set to clear when this condition occurred. In order to not eliminate low stratus clouds with this test, 9 pixels spaced 7 pixels apart in all directions were tested for a cloudy flag in the visible but clear in the IR. If two or more pixels met this condition, the visible cloudiness was not reset.

5.1.2 False clouds along coastlines in areas of high temperatures due to uncertainty of whether the RTNEPH surface temperature represented land or water

Since STC-METSAT could not obtain the classified land/water database used to create the RTNEPH surface temperatures, a proxy for this was created by building a composite of maximum and minimum surface temperatures for a two-week period and then marking as land those that exceeded a range of 2 K. This false land/water map in the RTNEPH projection was then remapped into the CHANCES database projection and compared with a 5-km resolution land/water map. Mismatched areas between these two databases were flagged as areas to check for possible false cloud detections. The CHANCES IR image was then interrogated in these areas from 45° N to 45° S for cloudiness and IR temperature less than 287 K. If these conditions were not met, the pixel was changed to clear.

5.1.3 Overestimation of cloudiness from IR data over northern South America

This problem was caused by a systematic warm bias in the RTNEPH temperature database over the South American continent north of the equator. An IR cloud climatology was examined to locate the bounds of the region in which the cloudiness was consistently overestimated. The IR cloud detection was then redone in this area using an adjusted temperature threshold.

5.1.4 Overestimation of cloud at night over certain desert regions

As above, a cloud climatology created from the CHANCES data was examined for systematic areas of abnormally high cloudiness over desert regions. The overdetection of cloud was the result of the RTNEPH surface temperature database not capturing the large diurnal temperature range in these regions. These areas were identified (certain areas in the Sahara and Omani deserts), and the IR cloud detection was redone with a fixed threshold of 285 K.

5.2 Preprocessing of Ancillary Data

In order to prepare the SSM/I, HIRAS upper air and DATSAV2 surface data for hourly, global processing by the global merge processor, a few preprocessing steps were necessary. These steps are described below:

5.2.1 Interpolate the 6-hourly HIRAS data to every hour

Since the HIRAS upper air fields of temperature, relative humidity, and height were only available at 0, 6, 12, and 18 UTC every day, these fields were linearly interpolated to 1-hr resolution. In addition, heights at the 1000 mb surface below 300 meters were set to 0 meters. This condition rarely occurred (mainly in the extreme South Atlantic), but it was necessary to correct in order for the height interpolation routines in the global merge processor to function correctly.

5.2.2 Persist DATSAV2 surface data

Due to global patterns of weather observation reporting, there were about twice as many SAO observations available at every third hour as compared to every hour (i.e., more at 0, 3, 9, 12, 15, 18, 21 UTC). This was largely due to missing observations from Eastern Bloc and Southern Hemisphere countries; Western Hemisphere nations had more consistent observations every hour. Figure 4 shows an example of the typical coverage over the Mediterranean region. About 7000 global observations would be available every third hour, but this number decreased to about 3500 at other hours. In order to account for this in the CLVL product, observations from the closest "third" hour were persisted to the "non-third" hours when no other observations were available. For

example, at 01 UTC the observation from 00 UTC would be persisted, and at 02 UTC the observation from 03 UTC was "backward persisted".

5.2.3 Split SSM/I data into 1-hour files

The raw SSM/I orbit files from the F10 and F11 SSM/I instruments were run through a program to create files with scan times from 30 minutes before the hour to 30 minutes after the hour. For example, the 12 UTC SSM/I file would contain scans from 1130 UTC to 1230 UTC.

5.3 Cloud Layer Assignment Algorithm

The following paragraphs describe the CLVL processing that takes place after all of the preprocessing steps described above. Also refer to Figure 5 in Appendix A and to the processing flow diagram in Appendix D.

The first step in the production of the global layered cloud product is to determine if cloudiness exists in the CHANCES cloud/no cloud data. This occurs about 51 percent of the time. Clear points are not processed any further.

For cloudy points, the height, relative humidity, and temperature fields are computed at the particular location in the CHANCES image. The fields at the four adjacent HIRAS grid boxes at each level are bilinearly interpolated to the location in the CHANCES image. Then a vertical sounding at the mandatory levels at the current location is constructed. From the temperature sounding, the height corresponding to the IR temperature is interpolated (hereafter referred to as Z(T)). The 1.5 km CLVL bin containing Z(T) is marked as cloudy in all cases. Visible/IR disagreement is checked from the CHANCES QA image. If this condition occurs (indicating stratus or cirrus type clouds), no further ancillary data are used to determine cloud layers. This is valid because we have a cloud type detection heavily influenced by satellite data. For these types of clouds, the cloud top Z(T) is determined from the IR temperature, and the base is set to the top minus 300 m. This default thickness comes from the RTNEPH (Kiess and Cox, 1988). Clouds marked as cirrus or stratus have bits set in the QA image.

The majority of the clouds are not classified as cirrus or stratus, and they are never classified as these at night since there are no visible data. Clouds not classified up to this step are sent to the general CLVL cloud layer assignment module, which merges in all available data (SSM/I, Surface Airways Observations (SAO), and upper air) to assign the 8 levels in the CLVL output.

The next step is to see if collocated SSM/I data indicates precipitation. SSM/I precipitation is determined using the global algorithm of Grody (1991). If precipitation is indicated, a 9 x 9 pixel box (approximately 45 x 45 km) around the center of the SSM/I field-of-view is marked as precipitating. This corresponds to the SSM/I footprint size for

the precipitation algorithm. If a CHANCES determined cloud is in a precipitating field-of-view, all layers below Z(T) are marked as cloudy.

Next, the SAO data are searched to find all observations within a critical radius of the current location: 150 km in the CLVL processing. If more than two stations are found, a Gaussian filter is used to objectively interpolate the SAO station fields (cloud bases, fog existence, precipitation). If only one or two SAO stations are found, a test is done to see if either is within 30 km of the current location. If so, the fields from the closest station are used. If no SAO stations are within 150 km, SAO data are not used in the cloud layer assignment.

Similar to the SSM/I precipitation test, a test is done for precipitation from the SAO data. If precipitation is located in the SAO data, all levels below Z(T) are marked as cloudy.

In the case of using nearest neighbor SAO data, the SAO precipitation assignment is straightforward. When the Gaussian data filter is used, the assignment is more complex since precipitation is a discrete field. Some stations may be reporting precipitation while others may not and the current location may lie somewhere in between. In order to assign the presence of precipitation from SAO data, a Gaussian analysis is done on the stations for the presence or absence of precipitation. Non-precipitating stations are assigned a value of -1 and precipitating stations are assigned a value of +1. Gaussian interpolation is then performed on this field and if the value returned at the current location is greater than zero, precipitation is assigned from the SAO data.

Fog is also a quantity reported in the SAO data and it is handled in the same manner as precipitation since it is also a discrete field. Locations indicated as having fog from the SAO data have the lowest layer (0-1.5 km) set as cloudy (other tests are done as well to see if higher levels are cloudy). Continuing with non-precipitating cloudy locations in the CHANCES database which can be influenced by SAO data, the cloud layers reported in the SAO data are examined. Gaussian or nearest neighbor interpolation of the cloud base heights is performed depending on the distance criteria given above. Since the DATSAV2 observations contain several cloud base descriptors, each of these is interpolated separately. These are ceiling height, low cloud base, and any additional cloud layers reported. Once the DATSAV cloud layers have been constructed, the corresponding bins in the CLVL cloud layer product are marked as cloudy.

For remaining non-precipitating clouds, regardless of whether they have SAO observations or not, the upper air sounding at the mandatory levels is tested to determine if there are any clouds indicated from the relative humidity profile. The methodology to do this follows from Wang and Rossow (1995), with the exception that relative humidity is not computed separately with respect to ice and water. In essence, this method looks for relative humidity in the layer (greater than 84 percent) and also

looks for sharp gradients between layers. Layers that are indicated to have cloud by the upper air method are marked as cloudy in the CLVL output layer product, and this occurrence is also noted in the QA database. Note that in all of the above tests to assign clouds to layers, no cloud is allowed to exist at a altitude greater than Z(T).

At this point in the CLVL cloud layer algorithm, all of the cloud layer tests have been completed. The next step is to convert the cloud layer heights to an above ground level scale, and to handle any unrealistic situations that may arise from this (For example: clouds below the ground, base above top). Figure 5 (Appendix A) shows examples of layered cloud products from the initial CLVL database. Figures 6-8 in Appendix A show sample displays of the output layered cloud product. Figure 6 is a montage of the frequency of occurrence of cloud for all 8 layers for the entire month of July, 1994. Figure 7 is a 3-dimensional rendering of a single 1-hour sample of the layered cloud database. Figure 8 shows the frequency of occurrence of multi-layered clouds (i.e., more than one layer of clouds analyzed) for the month of July, 1994.

The ETOPO5 global 5-minute (about 9 km) resolution topography database is used to convert heights from above sea level to above ground level coordinates. Bilinear interpolation is used to determine the elevation of the particular location in the CHANCES image.

The final step in the CLVL cloud layer assignment algorithm is to perform checks for any unrealistic clouds that might have been constructed. An example of such a cloud might be when a very warm cloud top (and very low Z(T)) is compared to the topography data and found to be below the surface. Such a case might arise in mountainous topography. A cloud like this would have its base and top set in the lowest 1 km of the atmosphere.

The following lists unrealistic physical conditions and the correction applied:

Condition	Correction
1. Z (T) < 0 meters	Cloud top = 1 meter
2. Cloud base from SAO data > Z (T)	Base = Z (T)
3. Z (T) minus altitude (cloud top below ground)	Cloud top = 1 meter
4. Cannot solve for Z (T) (i.e., isothermal atmosphere)	Assume standard lapse rate of 6.5° C/km and recompute

Note: The "error occurred" bit in the QA product is set to mark when these conditions occurred. In general, these conditions affected less than 1 percent of the clouds.

6. OUTPUT TO TAPE

Output tapes are built by writing compressed image files in hourly groups. Each group contains the visible, infrared, QA, and CNC image for 1 hr. One day of data (24 groups) is then written to a single tape. Each day of data is approximately 1.6 Gb, which is compressed using the Lempel-Ziv-Welch (LZW) compression algorithm, then written to tape. The tape format is contained in the user's guide in Appendix B.

7. SUMMARY

STC-METSAT has produced an innovative, multi-layer, global cloud product for a 30-day period in July, 1994 for use by researchers at the DoD Center for Geosciences at Colorado State University and their collaborators. Additional periods of this CHANCES layered-cloud (CLVL) product could be processed as required.

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APPENDIX A

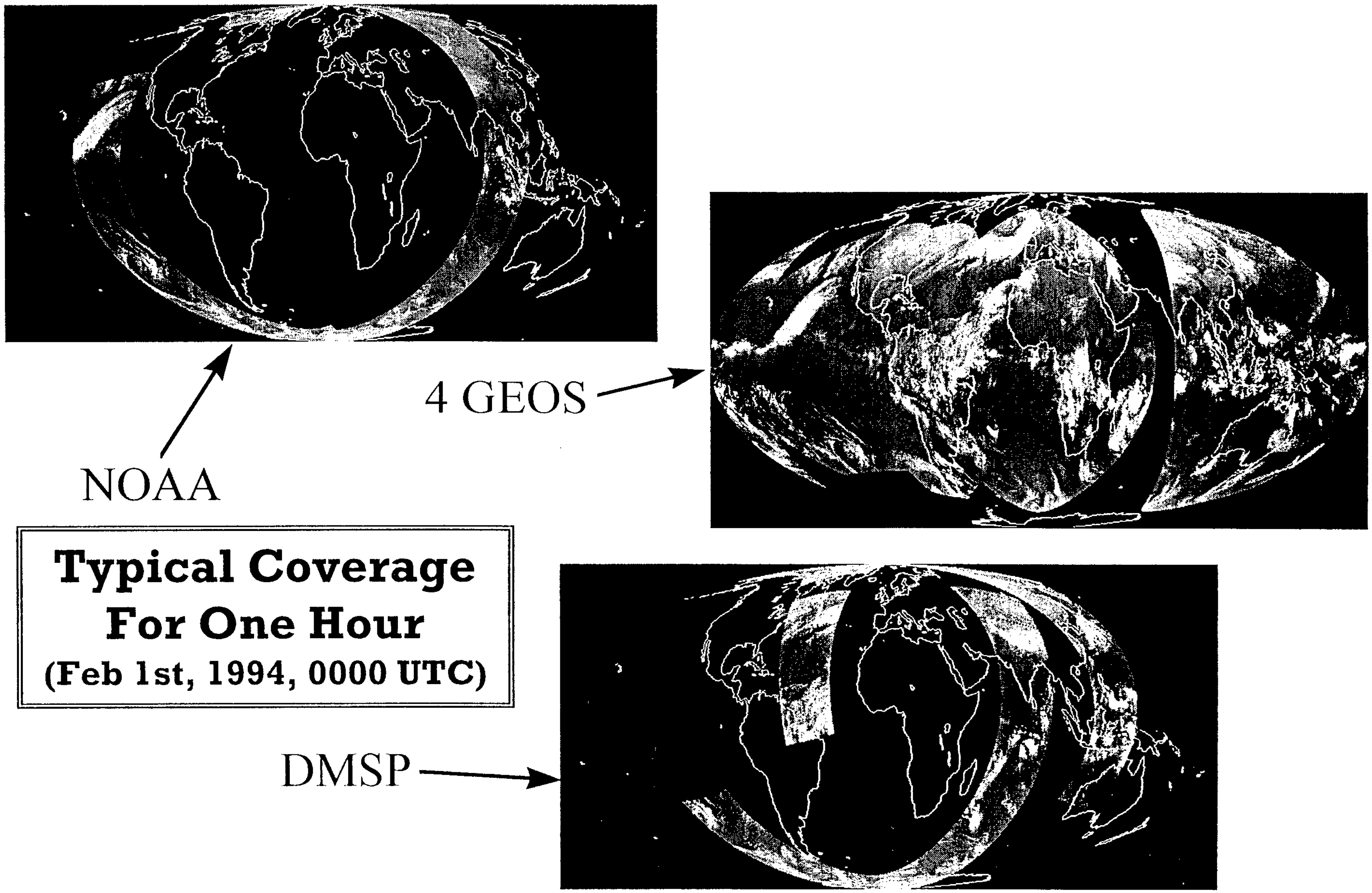


Figure 1. Input satellite data used for CHANCES project.

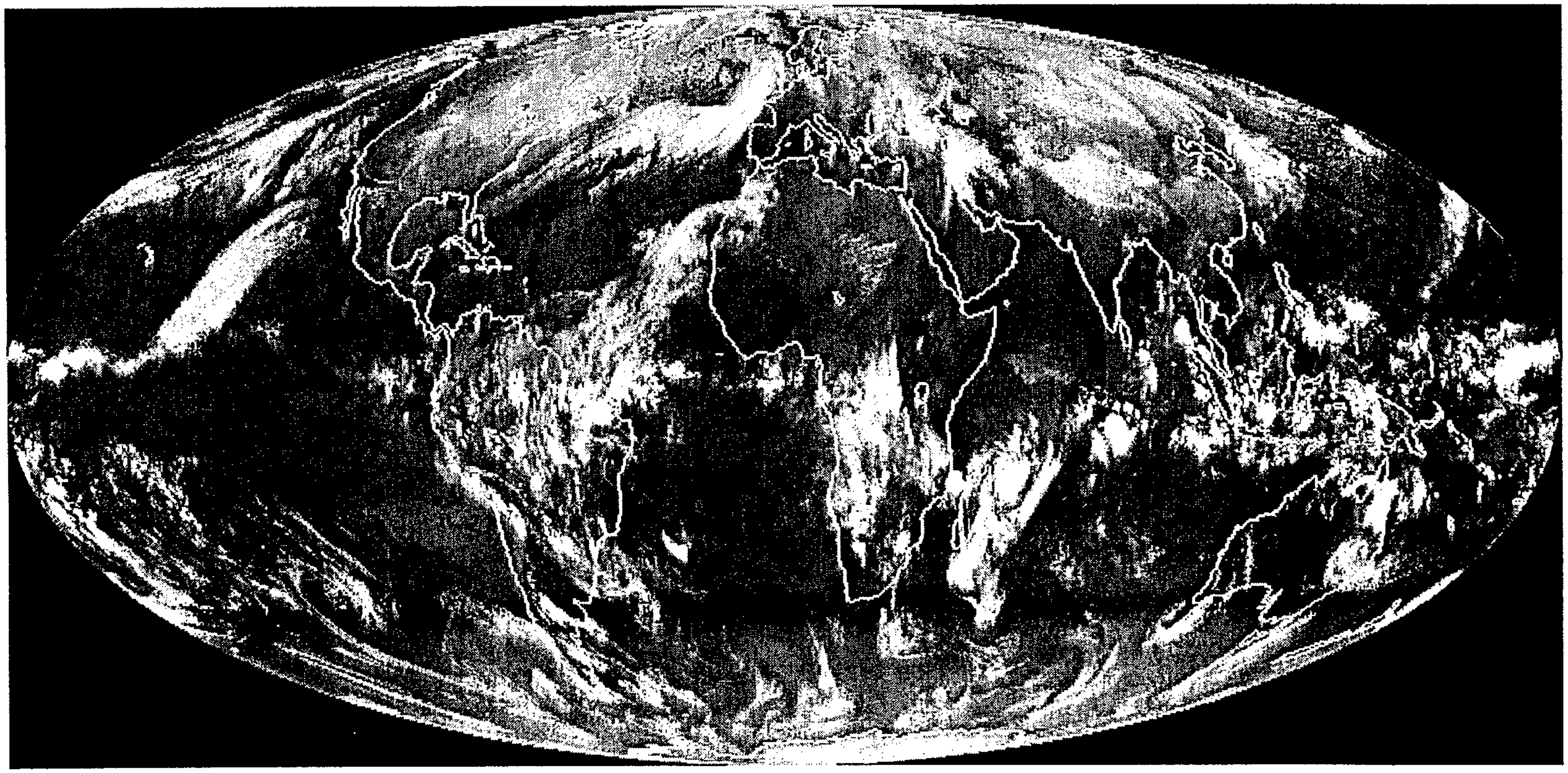


Figure 2. Example of CHANCES global infrared satellite image produced by merging all available images for one hour.

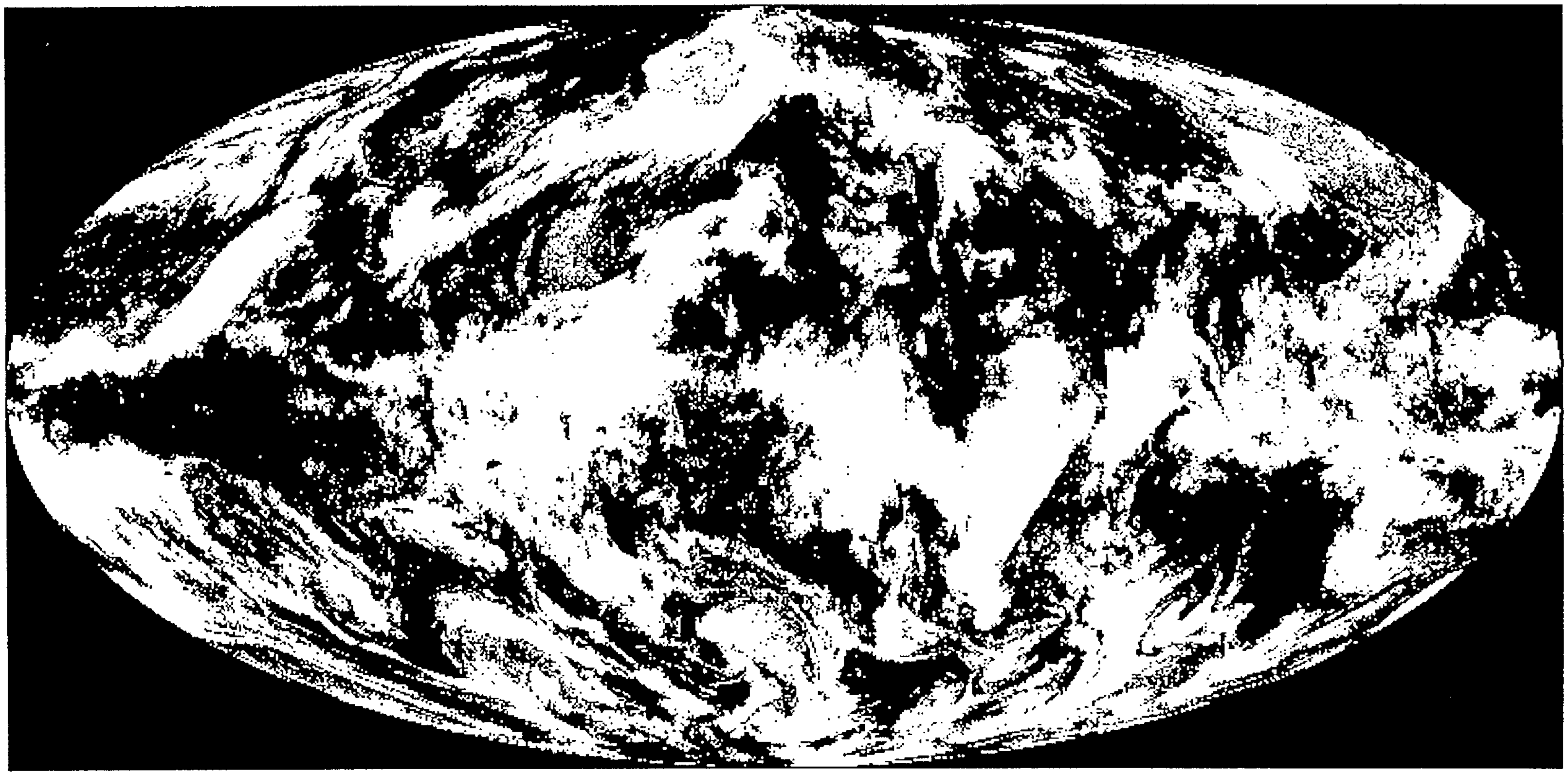
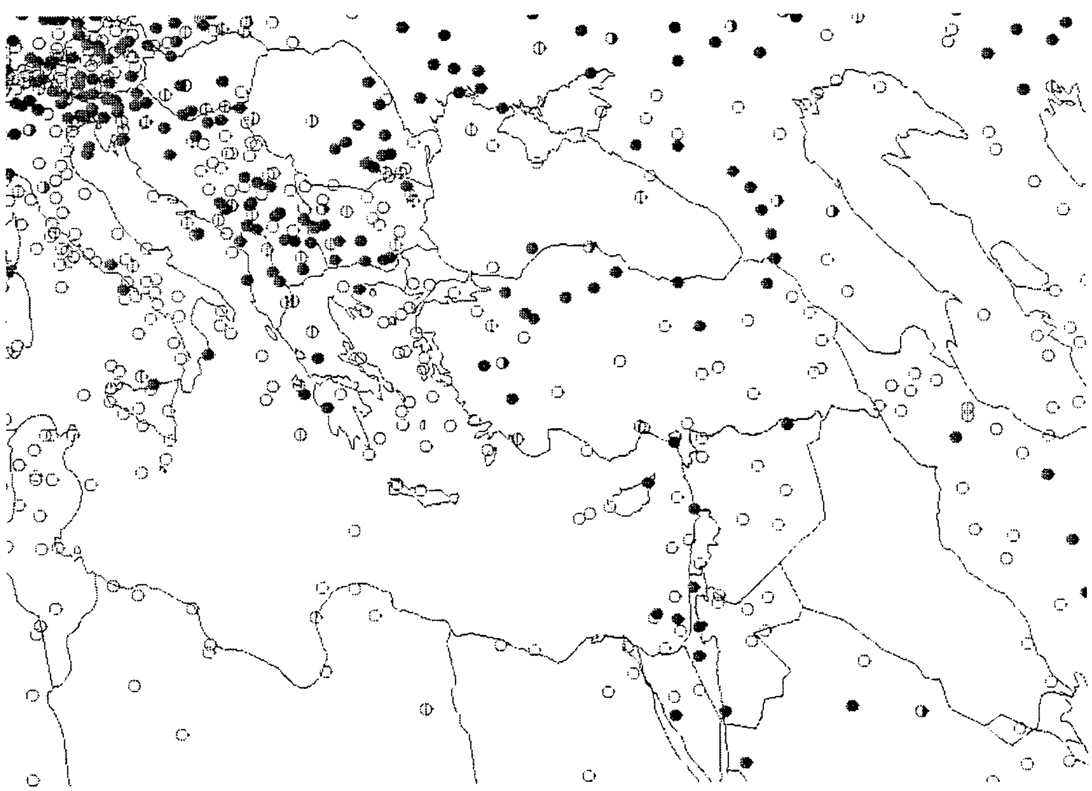


Figure 3. Example of CHANCES global cloud/no cloud (CNC) image for one hour.

Surface Observations for non-synoptic hours



Surface Observations for synoptic hours

Figure 4. Comparison of surface data availability for synoptic (3-hrly) vs. non-synoptic hours.

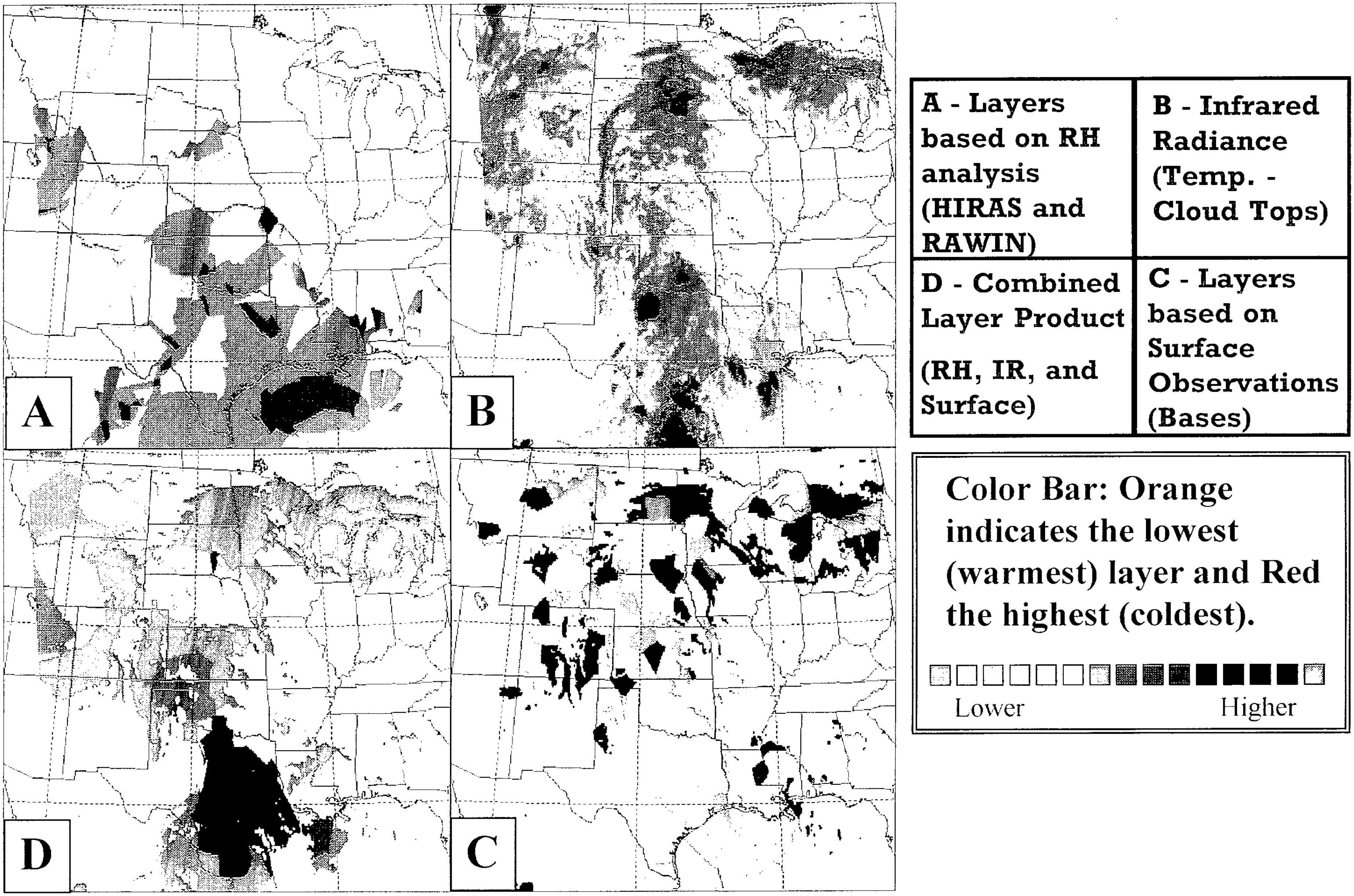
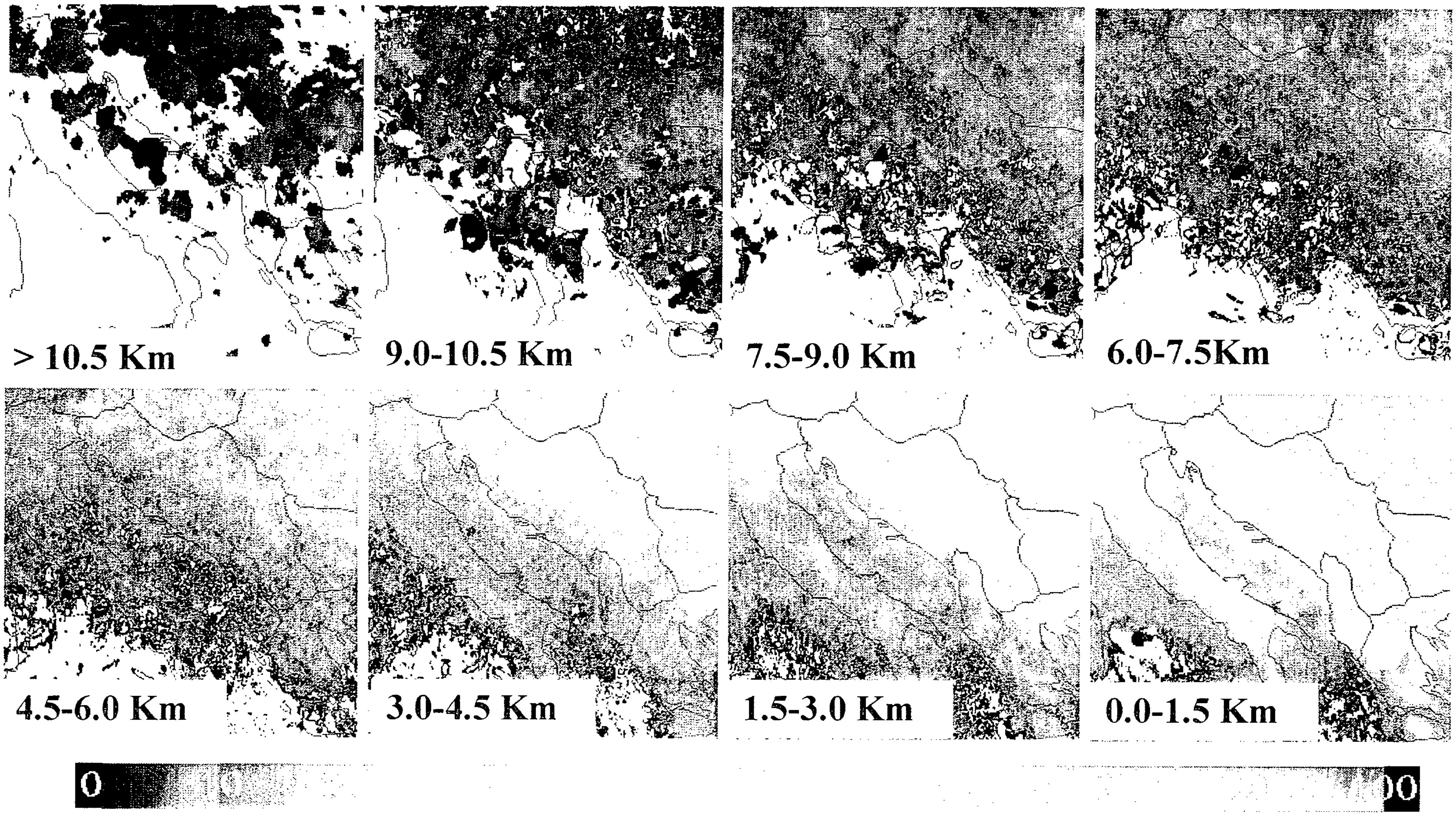


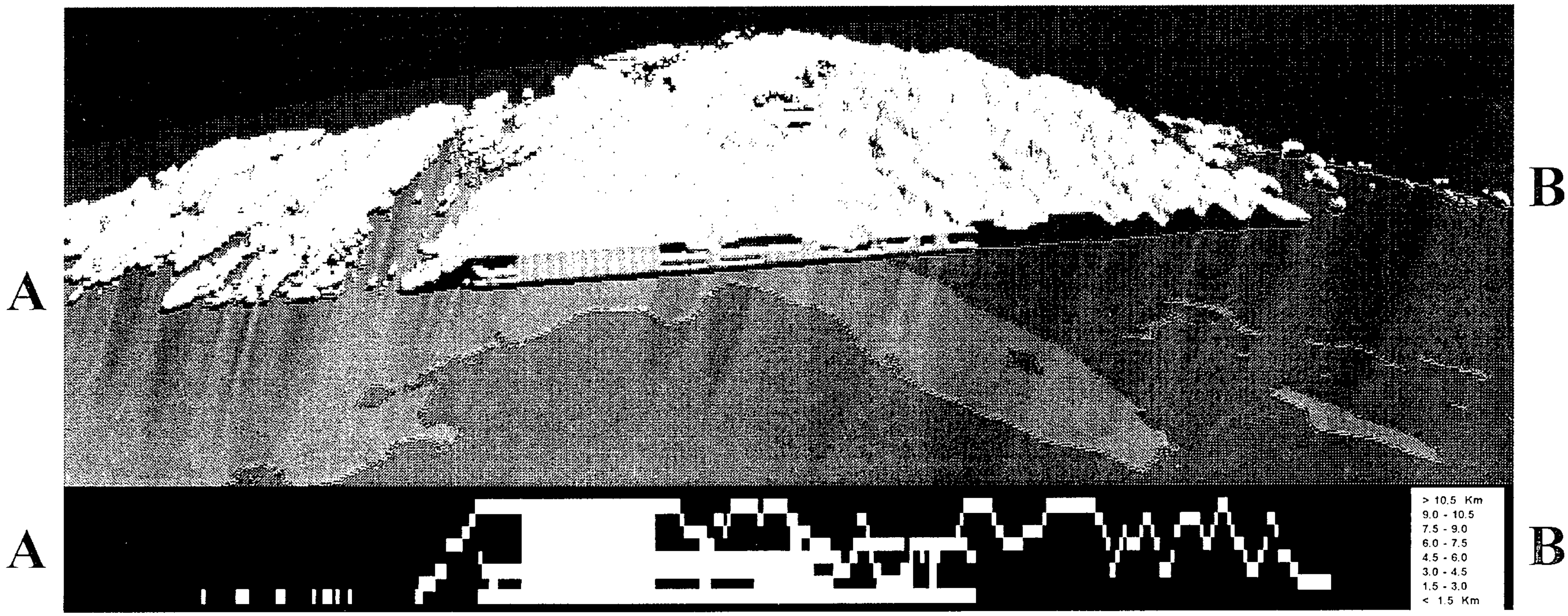
Figure 5. Examples of layered cloud products from relative humidity analysis, infrared radiance (cloud tops), surface observations, and the combined product.



Frequency of Occurrence of Cloud (%) in Each 1.5 Km Layer

July, 1994 (6-hrly composite - All heights above ground level)

Figure 6. Frequency of occurrence of cloud for all 8 layers based on CLVL data for the month of July, 1994. The region shown is centered on Bosnia.



3-D CROSS-SECTION OF CHANCES LAYERED CLOUD PRODUCT DERIVED FROM THE CHANCES SATELLITE IMAGE DATABASE

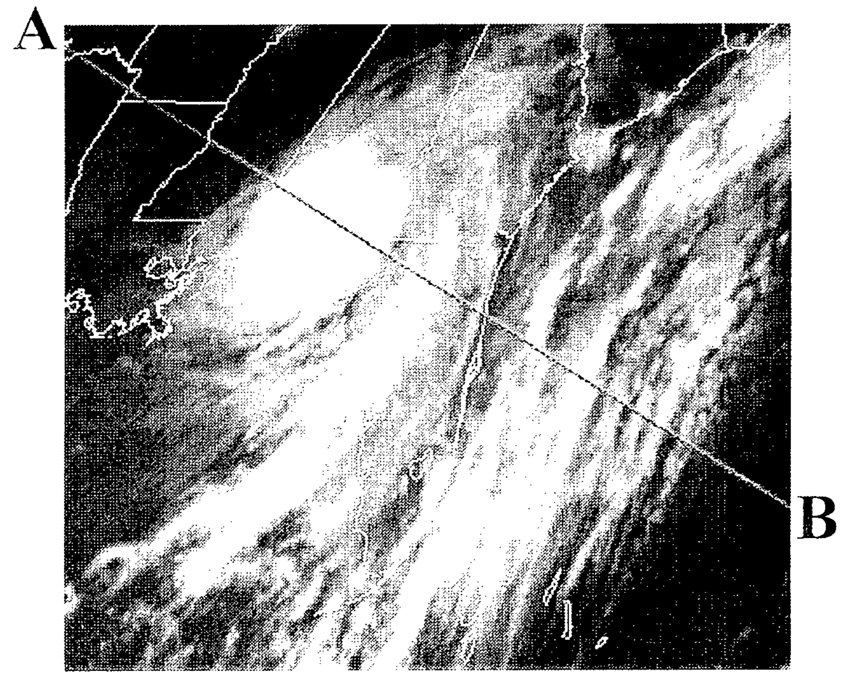


Figure 7. 3-dimensional rendering of a portion of the CLVL database.

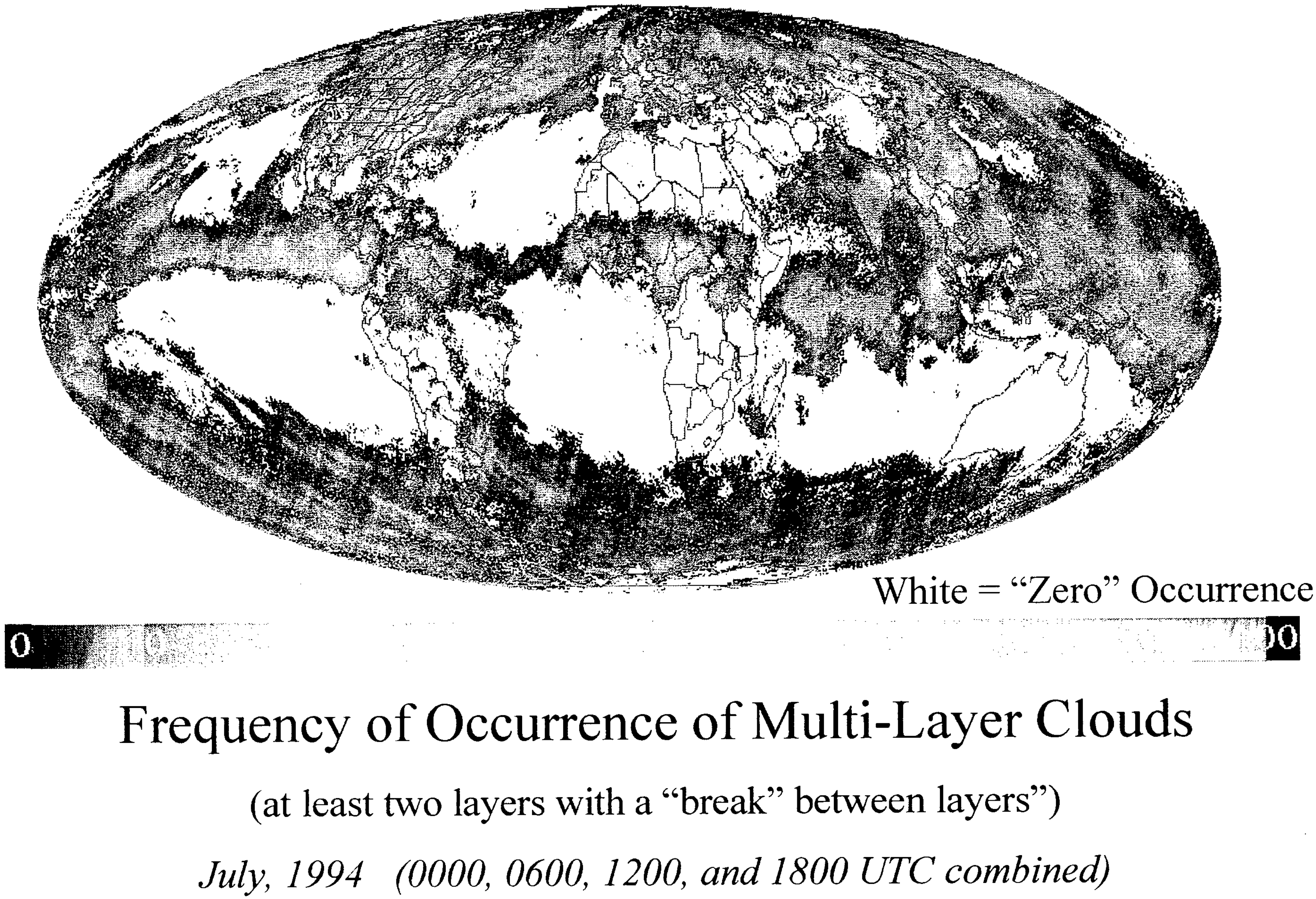


Figure 8. Frequency of occurrence of mult-layer clouds.

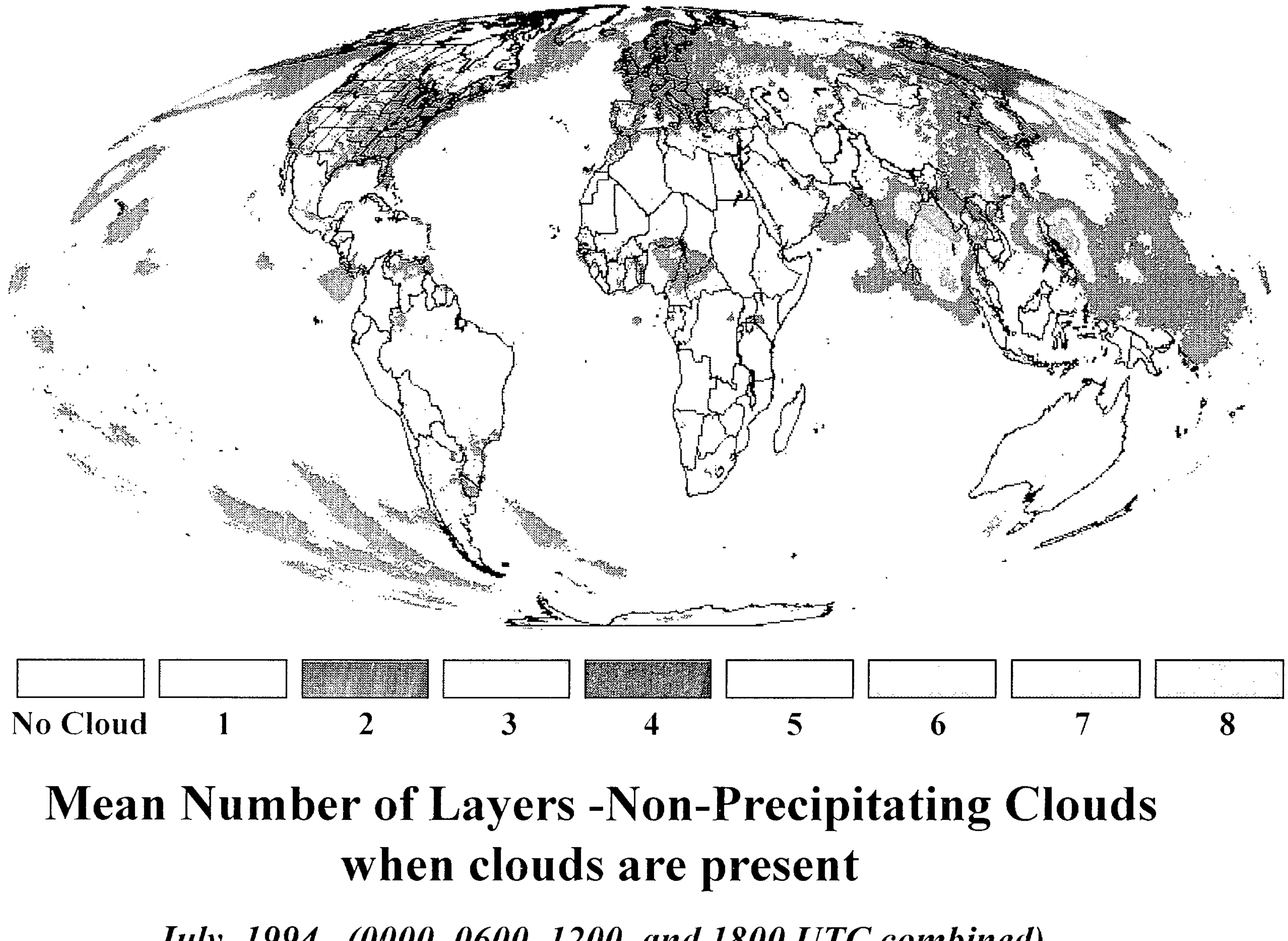


Figure 9. Mean number of layers of non-precipitating clouds when clouds are present.

APPENDIX B

APPENDIX B

CLVL DATA USER GUIDE

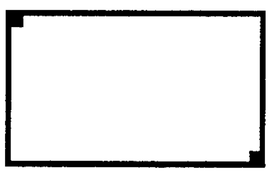
The User Guide consists of two parts. The first is a description of the output tape format and the algorithm for converting the Mollweide projection data points to latitude and longitude coordinates. The second is a database format specification for the two CLVL products, the cloud layer files and the QA files.

CLVL IMAGE SPECIFICATIONS

Full-resolution images:

8010 columns x 4006 rows
Cloud layer and QA images are stored by rows as raw data, 8-bits/pixel, no header.

(0,0) - upper left corner, first pixel in file, x=0, y=0



(8009,4005) - lower right corner, last pixel in file, x=8009, y=4005

Subsampled browse images:

800 columns x 401 rows
Cloud layer and QA subsampled images are stored by rows as raw data, 8-bits/pixel, no header.

(0,0) - upper left corner, first pixel in file, x=0, y=0
(799,400) - lower right corner, last pixel in file, x=799, y=400

Data interpretation for both full-resolution and subsampled images:

Cloud layer byte data:	1 in a bit position = Cloud in specified layer 0 in a bit position = No cloud in specified layer
QA byte data:	individual bits have meaning, consult database format documentation

CLVL IMAGE TAPE ARCHIVE

Each hour of CLVL data consists of 2 images. For any hour (00Z - 23Z), there exists on tape a **tar** file containing two full-resolution images from that hour (cloud layer and QA). In addition, the very first **tar** file on each tape contains the full day in a set of subsampled, low-resolution images conducive to browsing. The filename naming convention is as follows:

Full-resolution images:

YYDDDHHt.mrg

YY	= last 2 digits of year
DDD	= day of year
HH	= UTC hour
t	= image type, will be one of the following:
l	= cloud layer image
s	= QA

Subsampled images:

YYDDDHHgt.img

YY	= last 2 digits of year
DDD	= day of year
HH	= UTC hour
g	= constant letter denoting "global subsample"
t	= image type, will be one of the following:
l	= cloud layer image
s	= QA

To extract a 24-hour set of subsampled images from tape (first tar set on tape):

tar xv command to extract tar file set from tape

To extract a single hour set of full-resolution images from tape:

mt fsf 1	command to move tape pointer from previous to next tar set
tar xv	command to extract tar file set from tape

Repeat the above procedure to extract each hour set of files.

The files were compressed using the UNIX **compress** utility which uses a lossless algorithm. To uncompress the files:

uncompress -v <filename> uncompresses files, wildcards allowed

The file sizes after using **uncompress** should be as follows:

Full-resolution images = 8010x4006x8 bits = 32,088,060 bytes
Subsampled images = 800x401x8 bits = 320,800 bytes

CLVL COORDINATE CONVERSION

All images are in the Mollweide projection.
Given a lat/lon pair, to find the x,y coordinates in the merge image:

-90<= LAT <=+90
-179.95<= LON <=+180

columns in full-resolution images = 8010
rows in full-resolution images = 4006

columns in subsampled images = 800
rows in subsampled images = 401

x = ((((lon/180)*cos(lat))+1)*(#columns/2))-1

y = (sin(-lat)+1)*((#rows-1)/2)

APPENDIX C

APPENDIX C

CLVL IMAGE FORMATS

Cloud Layer Image Format:
One byte per pixel. Each pixel will contain cloud layer information as specified in the following table. The appropriate layer bit is set to 1 if a cloud is present. All elevations are given in kilometers above ground level.

BIT POSITION	FIELD NAME	SIZE	RANGE
7	> 10.5 km Cloud Layer	1 Bit	0 - 1
6	>9.0 - 10.5 km Cloud Layer	1 Bit	0 - 1
5	>7.5 - 9.0 km Cloud Layer	1 Bit	0 - 1
4	>6.0 - 7.5 km Cloud Layer	1 Bit	0 - 1
3	>4.5 - 6.0 km Cloud Layer	1 Bit	0 - 1
2	>3.0 - 4.5 km Cloud Layer	1 Bit	0 - 1
1	>1.5 - 3.0 km Cloud Layer	1 Bit	0 - 1
0	0 - 1.5 km Cloud Layer	1 Bit	0 - 1

128	64	32	16	8	4	2	1
MSB							LSB
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
> 10.5	9.0-10.5	7.5-9.0	6.0-7.5	4.5-6.0	3.0-4.5	1.5-3.0	0-1.5

QA Image Format:
One byte per pixel. Each pixel will contain information as specified in the following table. Bits are set only where the original CHANCES data indicates clouds. Clear areas set all bits to zero. Off earth condition sets bits 4 and 5 to one.

BIT POSITION	FIELD NAME	SIZE	RANGE
7	Precipitation detected	1 Bit	0 - 1
6	HIRAS/Wang & Rossow cloud	1 Bit	0 - 1
5	Cirrus detected	1 Bit	0 - 1
4	Stratus detected	1 Bit	0 - 1
3	SSM/I data available	1 Bit	0 - 1
2	SAO data available	1 Bit	0 - 1
1	Filled CHANCES cloud	1 Bit	0 - 1
0	Error condition	1 Bit	0 - 1

128	64	32	16	8	4	2	1
MSB							LSB
BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
Precip	HIRAS cloud	Cirrus	Stratus	SSM/I avail	SAO avail	Filled cloud	Error

QA Image Bit Interpretation:

PRECIPITATION FIELD:

VALUE	INTERPRETATION	VALUE	INTERPRETATION
1	Precipitation detected from SAO or SSM/I	0	No precipitation

HIRAS/WANG AND ROSSOW CLOUD FIELD:

VALUE	INTERPRETATION	VALUE	INTERPRETATION
1	Cloud detected by HIRAS / Wang and Rossow method	0	No cloud by HIRAS / Wang and Rossow method

CIRRUS FIELD:

VALUE	INTERPRETATION	VALUE	INTERPRETATION
1	Cirrus detected (Cloudy IR, Clear Visible)	0	No cirrus

STRATUS FIELD:

VALUE	INTERPRETATION	VALUE	INTERPRETATION
1	Stratus detected (Clear IR, Cloudy Visible)	0	No stratus

SSM/I DATA AVAILABILITY FIELD:

VALUE	INTERPRETATION	VALUE	INTERPRETATION
1	SSM/I data available	0	No SSM/I available

SAO DATA AVAILABILITY FIELD:

VALUE	INTERPRETATION	VALUE	INTERPRETATION
1	SAO data available	0	No SAO available

FILLED DATA FIELD:

VALUE	INTERPRETATION	VALUE	INTERPRETATION
1	Filled CHANCES data (interpolated or persisted data)	0	No filled CHANCES data

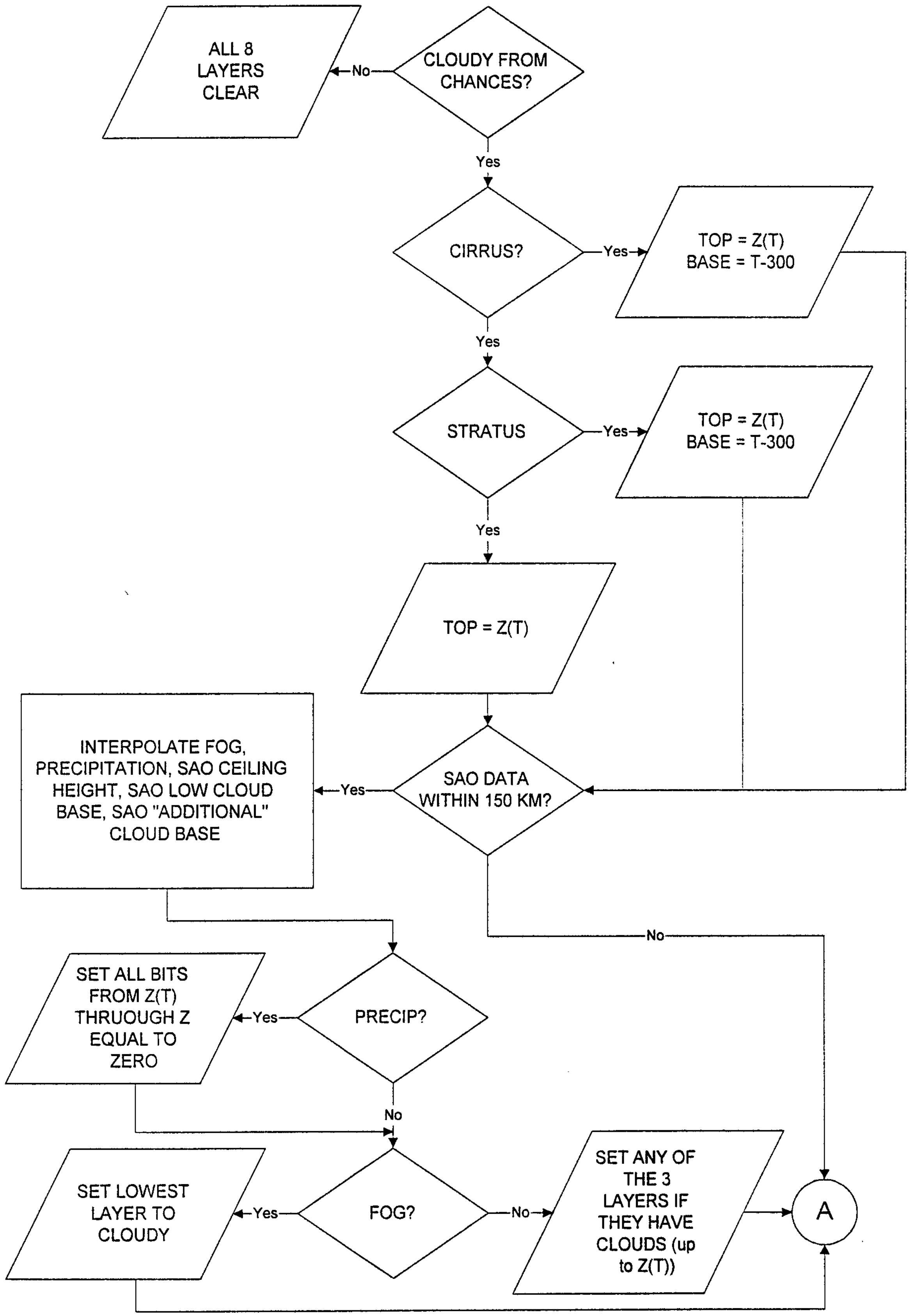
ERROR FIELD:

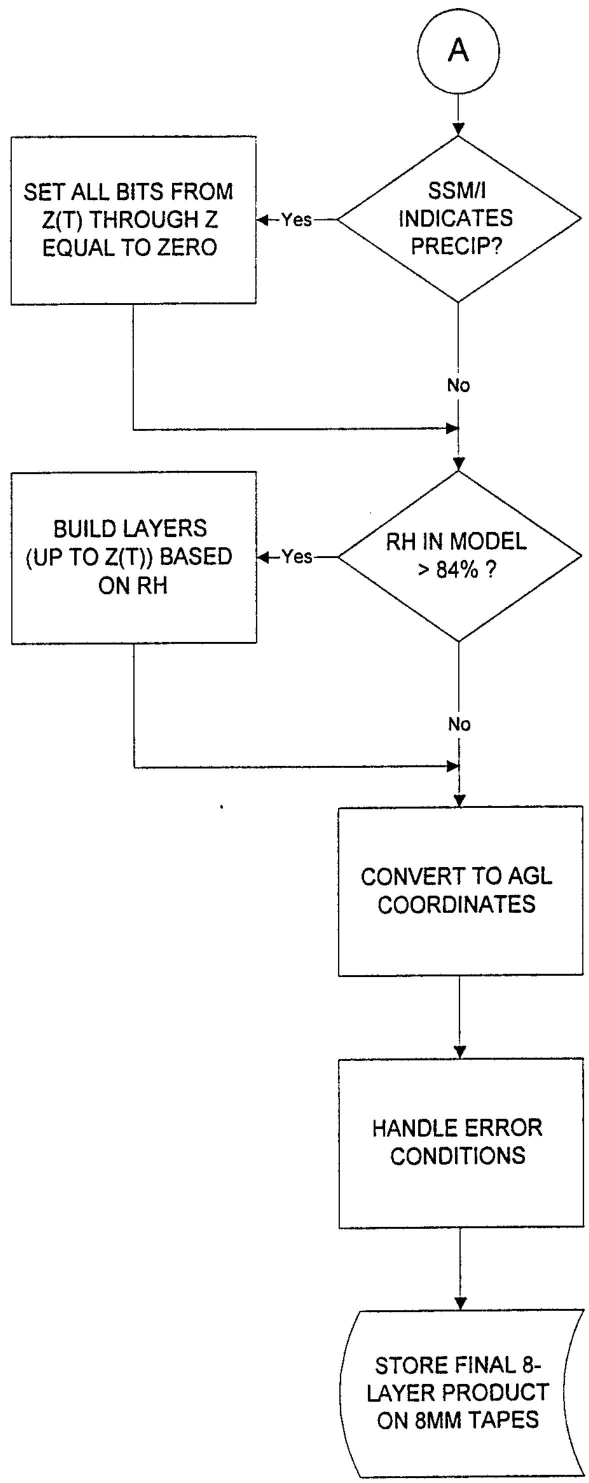
VALUE	INTERPRETATION	VALUE	INTERPRETATION
1	Error condition (cloud top below surface, cloud base below surface, cloud base higher than cloud top)	0	No error

APPENDIX D

Appendix D

Layered Cloud Processing Flow Diagram




A
SSM/I INDICATES PRECIP?
Yes
SET ALL BITS FROM Z(T) THROUGH Z EQUAL TO ZERO
No
RH IN MODEL > 84% ?
Yes
BUILD LAYERS (UP TO Z(T)) BASED ON RH
No
CONVERT TO AGL COORDINATES
HANDLE ERROR CONDITIONS
STORE FINAL 8-LAYER PRODUCT ON 8MM TAPES